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SILVICAL CHARACTERISTICS OF SUGAR PINE

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Preface

The Forest Service is engaged in assembling information on the silvical characteristics of important forest trees of the United States. Much material that is of value in silviculture and research is widely scattered and difficult to locate. This report presents, in preliminary form, the information that has been collected for one species of tree. Similar reports are being prepared for other species at the California Forest and Range Experiment Station and at other forest experiment stations. Readers are encouraged to notify the authors of omissions, errors, or new information affecting the silvical characteristics of the species.

The California Forest and Range Experiment Station is maintained by the Forest Service, U. S. Department of Agriculture, at Berkeley, California, in cooperation with the University of California.

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By H. A. Fowells [1] and Gilbert H. Schubert [2]

Sugar pine (Pinus lambertiana Dougl.), the largest and most valuable of the western pines, is native to Oregon, California, and Lower California. Its range extends from the North Fork of the Santiam River on the west slope of the Cascade Ranges in Oregon, through the Sierra Nevada and North Coast Ranges in California, in scattered mountain ranges in southern California, and to Mount San Pedro Martir in Lower California (fig. 1).

HABITAT CONDITIONS

CLIMATIC

The climate in which sugar pine grows may generally be called humid, according to Thornthwaite's classification (41). More specifically it is characterized by:

> . . . dry summers, with July and August precipitation usually less than 1 inch per month.
>
> . . . annual temperature extremes of below -10° F. to above 100° F.
>
> . . . annual precipitation of about 25 inches or more, part of which falls as snow.

The tree's lower limit of precipitation may be about 20 inches a year, for isolated sugar pines are found in the Pacific ponderosa pine type (37) where precipitation is 18 to 20 inches. Its lower temperature limit has not been determined but probably is below -30° F.

EDAPHIC

Sugar pine grows on many different kinds of soils, from shallow stony or rocky alkaline clays to loose, deep, well-drained, moderately acid sandy loams. These soils may develop from weathering of a wide range of parent rocks: Rhyolite, andesite, diorite,

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2/ Forester, Division of Forest Management Research, California Forest and Range Experiment Station.

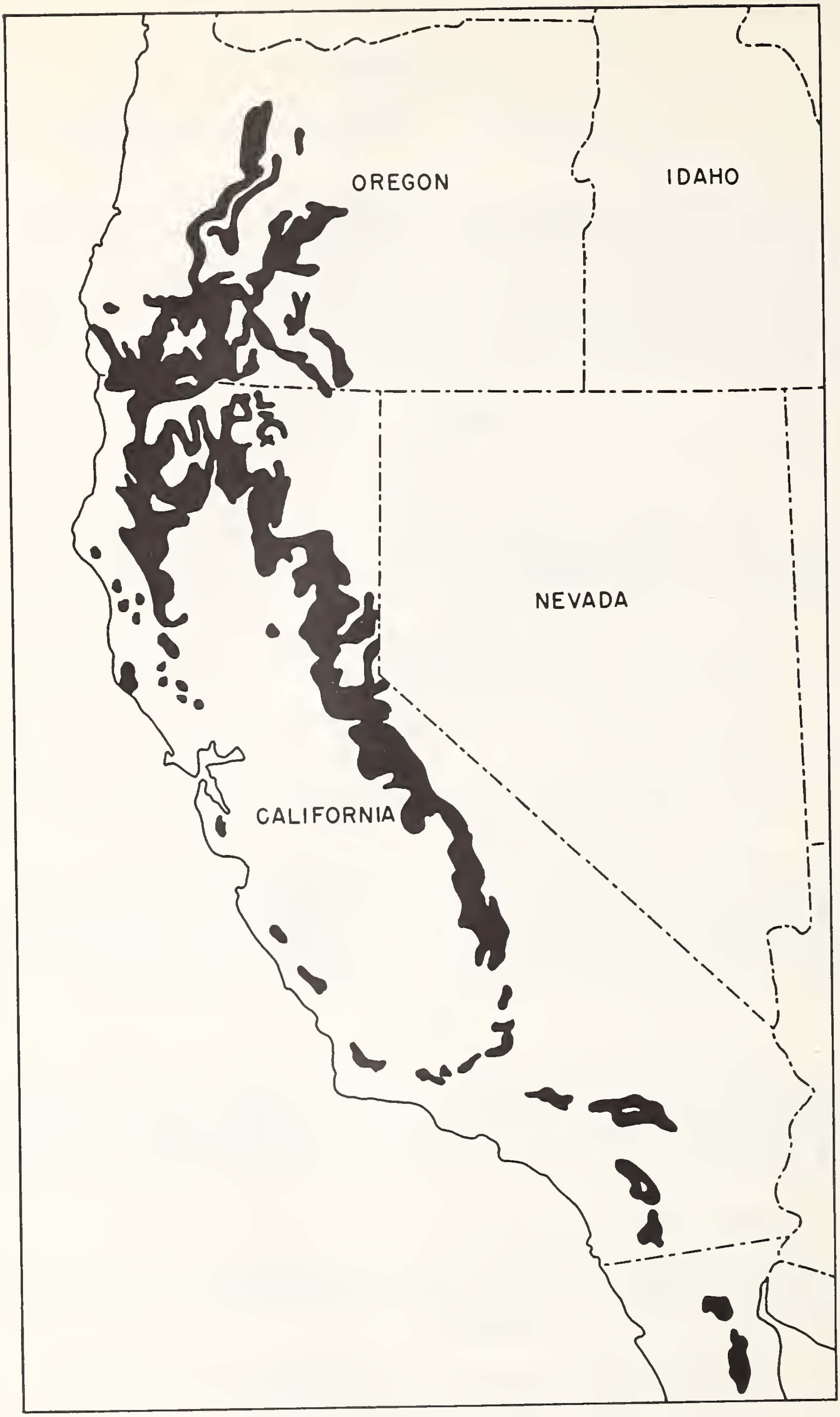

Figure 1.--The natural range of sugar pine.

sandstone, shale, basalt, and granitic or metamorphic equivalents. The Holland, Olympic, Aiken and Josephine soil series are the most common.

The best stands in the central Sierra Nevada grow on deep, sandy loam soils of the Holland series, developed from granitic rock. In the southern Cascade Range the best stands are on deep clay loams developed on basalt and rhyolite. In the northern Sierra Nevada and Cascade Mountains, sugar pine grows on loam to silty clay loam soils, brown to dark reddish-brown in color and slightly to moderately acid in reaction. Pumice soils here also support excellent stands, especially on benches and gentle slopes where the soils are deep, coarse textured, and well-drained.

In the Coast Range and Siskiyou Mountains in California and Oregon, the best stands are on light brown to reddish-brown, slightly to moderately acid, silt loams and clay loams derived from sandstone and shale. The poorest stands usually grow on red clay loam developed in place from weathering of peridotite and related ultrabasic rocks which in places are partially serpentinized.

PHYSIOGRAPHIC

At its northern limits, about latitude 44° 47' N., sugar pine grows between elevations of 1,700 and 3,700 feet (39); farther south in Oregon from about 1,100 feet to 5,400 feet. East of the Cascade summit it occurs up to 6,500 feet in Klamath County. In northern California it grows as high as 7,500 feet (latitude 41° 23' N.) and as low as 2,000 feet in the Sacramento canyon. In the central Sierra Nevada it ranges from 2,000 to 7,800 feet, as in Yosemite National Park (latitude 37° 44' N.). In southern California it occurs at from 4,000 to 10,500 feet in the San Bernardino Mountains (latitude 34° 15' N.), and in Lower California it is common at elevations of 8,000 to 10,000 feet in the San Pedro Martir Plateau (latitude 30° 30' N.).

The best stands of sugar pine occur in an elevational belt between 4,500 and 6,000 in the central Sierra, from the San Joaquin River north to the American River (latitudes 37° and 39° N.).

At the lower and middle elevations in the Sierra Nevada, sugar pine is most common on north and east facing slopes. In southern Oregon it grows on all aspects in equal abundance at lower elevations, but mostly on the warmer aspects at high ones.

BIOTIC

Sugar pine is one of the major timber species in the Transition Life Zone (26) in the Cascade-Sierra Range and Siskiyou Mountains. It is represented in nine cover types of western North

American (37), occurring as single trees or small groups but never in pure stands over extensive areas. It is one of the major components in the ponderosa pine-sugar pine-fir type (sometimes called the mixed conifer type) and as a minor component in the following cover types: California red fir, white fir, Pacific Douglas-fir, Port-Orford-cedar--Douglas-fir, Pacific ponderosa pine--Douglas-fir, Pacific ponderosa pine, California black oak, and Jeffrey pine.

In the northern part of its range it is commonly associated with Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), ponderosa pine (*P. ponderosa* Laws.), grand fir (*Abies grandis* (Dougl.) Lindl.), incense-cedar (*Librocedrus decurrens* Torr.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western redcedar (*Thuja plicata* Donn), and Port-Orford-cedar (*Chamaecyparis lawsoniana* (A. Murr.) Parl.).

In the central portions it is associated with ponderosa pine, Jeffrey pine (*P. jeffreyi* Grev. & Balf.), white fir (*A. concolor* (Gord. & Glend.) Lindl.), incense-cedar, California red fir (*A. magnifica* A. Murr.), and giant sequoia (*Sequoia gigantea* (Lindl.) Decne.) (fig. 2).

Farther south, common associates are: Jeffrey pine, ponderosa pine, Coulter pine (*P. coulteri* D. Don) and bigcone Douglas-fir (*Pseudotsuga macrocarpa* (Vasey) Mayr). As elevation increases, white fir and giant sequoia are added and at the upper limits, Jeffrey pine, western white pine (*P. monticola* Dougl.), California red fir, and lodgepole pine (*P. contorta* Dougl.).

Common brush species in the sugar pine range include greenleaf manzanita (*Arctostaphylos patula* Greene), deerbrush (*Ceanothus integerrimus* H. & A.), snowbrush (*C. velutinus* Dougl.), whitethorn (*C. cordulatus* Kell.), bearmat (*Chamaebatia foliolosa* Benth.), chinkapin (*Castanopsis sempervirens* Dudley), salal (*Gaultheria shallon* Pursh.), and coast rhododendron (*Rhododendron californicum* Hook.) (21).

LIFE HISTORY

SEEDING HABITS

Flowering and fruiting

Sugar pine flower buds are formed during July and August, but are not discernible until early the next summer (16). On the Stanislaus National Forest at about 6,000 feet, staminate strobili are visible about the middle of June; pistillate strobili a week or two later. Pollen shedding occurs after the middle of May at elevations below 3,000 feet and about the first week in July at 6,000 feet (5). The conelets are from 1 to 2 inches long at the time of pollen dissemination, and they grow to 2 or 3 inches by the

Figure 2.--Sugar pine (far left and third from the left) growing with ponderosa pine. White fir reproduction and manzanita in the understory.

end of the first growing season. The cones reach mature size--average approximately 12 inches with some exceptional cones measuring more than 22 inches--by late August of the second year and contain, on the average, 210 developed seeds per cone.

Time of ripening of cones differs a great deal in different parts of the range. In Oregon, at 1,000 feet elevation in the Rogue River Valley the cones usually open between August 15 and 20. From 2,000 to 3,000 feet in the Umpqua River drainage, cones open 2 to 4 weeks later. [3/] In California at 5,000 to 6,000 feet on the Stanislaus National Forest, the cones usually do not open until late in September or early in October.

Seed production

Seed production of sugar pine varies with tree size and dominance class. Some trees begin to bear a few cones when they are about 8 inches d.b.h.; however, they do not become good producers until they are about 30 inches in diameter, or about 150 years of age (16).

Almost all sugar pine cones, 98 percent in one study, are produced on the larger dominant trees. Trees less than 14 inches in diameter averaged less than 8 cones per tree per crop (16). Those over 50 inches averaged 100 or more cones. The most cones reported on a single tree was 848 on a 48-inch tree, equivalent to about 170,000 seeds, or 85 pounds.

Individual trees do not produce cones every year and relatively few have cones every other year. Heavy cone crops are borne at intervals of 2 to 7 years--the average being about 4 years. There is some evidence that the size of sugar pine cone crops can be increased by applications of ammonium phosphate fertilizer (34).

Many of the cones which appear on the trees during the spring of the second year fail to survive to maturity. Squirrels, particularly the Douglas pine squirrel (*Tamiasciurus douglasii*), at times cut down as many as half of the cones before they mature (16, 40). Birds, particularly the white-headed woodpecker (*Dendrocopos albolarvatus*), may completely riddle a third or more of the immature cones (40). Sugar pine cone beetles (*Conophthorus lambertianae* Hopk.) destroy many sugar pine cones (16, 17, 27), and their attacks are believed to be one of the major reasons for the lack of successive heavy cone crops (16). Subfreezing weather during the late spring of the second year can injure sugar pine conelets (32).

3/ Unpublished data, Pacific Northwest Forest and Range Experiment Station.

Seed dissemination

Natural seed dissemination begins in late August at the lowest elevations and in September at higher levels. It continues through October, and some seeds fall during the winter months. Most of the sound seed is shed by the end of October; after this most seeds are undeveloped. The cones begin to open when their specific gravity has dropped to 0.62 or lower (33).

Practically all sugar pine seeds are disseminated by wind. Rodents and birds are minor factors in seed dispersal. Some seeds are buried by rodents at considerable distances from the seed tree, but many are consumed during the winter and early spring. A few of the seeds buried by rodents remain in the soil and germinate, but the seedlings usually come up in dense clumps.

Sugar pine seeds are large (about 2,000 per pound) and have a relatively small wing for their weight. Consequently they are not carried great distances by air currents. In still air, the seed falls at the rate of 8.7 feet per second (36). In one study 80 percent of the seeds fell within 100 feet of the seed trees, but some were carried as much as 200 feet (13).

The number of seed shed per acre, of course, varies with the number and size of seed trees. The largest number observed in California was 180,000 sound seeds per acre in a cutover stand which had 5 cone-bearing trees per acre, each of which bore an average of 167 cones (16).

VEGETATIVE REPRODUCTION

Sugar pine does not reproduce itself naturally by sprouts. Moreover, sugar pine cuttings do not root easily; in one test (29) only 2 percent of the cuttings rooted although calluses formed on the stems of others. But the cuttings were from a 12-year-old tree--younger material might root more readily.

Sugar pine can be grafted onto stocks of other pines. For example, successful grafts were made on stock of ponderosa pine and Monterey pine (*pinus radiata* D. Don), which are not closely related to the white pines (28).

SEEDLING DEVELOPMENT

Establishment

The germination of sugar pine is epigeous (cotyledons appear above the ground). The rate of germination is as high as or higher than that of its associated species (42). In one field test the germination rates were: Sugar pine 70 percent; ponderosa pine, 53; incense-cedar, 32; and white fir, 21 (15). Germination of sugar pine in seedspots in southern Oregon was equal to or higher than that of ponderosa pine and higher than Douglas-fir (38).

Sugar pine seeds are eagerly sought after by forest rodents, so little seed may germinate. Early reports that the viability of sugar pine seed was low and that sugar pine seedlings were not vigorous probably arose from the observed relative scarcity of reproduction. But destruction of the seed may have been another reason for the scarcity.

Although it is almost axiomatic that pine seeds germinate better on mineral soil, several field tests show that mineral soil is not necessarily superior for sugar pine. In one test of surface conditions, 70 percent of the sugar pine seed germinated on a mineral soil surface, compared to 54 percent on a litter-covered surface (15). In another test germination was little different on bare and on litter covered surfaces--62 percent on bare compared to 65 percent on litter one year, and 42 percent on bare against 50 percent on litter another year.

During their first year sugar pine seedlings are exceptionally vigorous, compared to their natural associates. In an 8-year study of establishment of seedlings, the first year survival of sugar pine seedlings was 42 percent--compared to 27 percent for ponderosa pine, 11 percent for white fir, and 12 percent for incense-cedar. In southwestern Oregon seed-spotting tests, first year stocking of sugar pine seedlings was 59 percent, of ponderosa pine 49 percent, and of Douglas-fir 16 percent (38).

Brush hinders the establishment and growth of sugar pine seedlings. In 18 to 24 years only 18 percent of the 1-year-old seedlings starting under brush survived (14). At the end of 10 years the tallest were barely over a foot high and still overtopped by the brush. Where sugar pine had an even start with brush, however, it has been able to compete successfully (12).

One reason for the better survival of sugar pine seedlings during their first year is that the seedlings are only slightly attacked by cutworms (Noctuidae). The California Station found that only 8 percent of the sugar pine seedlings were killed by cutworms, whereas 28 percent of the ponderosa pine, 34 percent of the white fir, and 53 percent of the incense-cedar seedlings were killed by these insects (10).

Sugar pine seedlings are more susceptible to freezing injury than ponderosa pine, Jeffrey pine, and incense-cedar seedlings, but they are slightly less damaged by freezing than white fir (31).

Drought may cause high mortality of sugar pine seedlings. In one 8-year study about half of the losses were attributed to drought. However, losses from low soil moisture were no greater for sugar pine than for ponderosa pine and white fir.

Rodents destroy many seedlings during the first 2 months after germination.

Records of seedling mortality in Oregon show no losses from heat injury even where seedlings grew through beds of charcoal on south exposures. 4/

Seedling mortality is greatest during the first 2 years (14). About 55 percent of the sugar pine seedlings on a series of natural reproduction plots were lost during the first year and 66 percent failed to survive 2 growing seasons. The mortality rate decreased after the second year and had almost leveled off by the tenth year.

The seed-to-seedling ratio is one measure of the effectiveness of different methods used to secure natural regeneration. This ratio was found to vary greatly, depending mainly on the condition of the seedbed and the amount of seed destroyed by animals. On three different areas the ratios were: 38 seeds per seedling when the ground surface was scarified and the rodents were poisoned; 70 when the area was only scarified; and more than 480 when no preparatory measures were taken (16).

On the basis of these data, it appears that natural sugar pine regeneration would be favored by a group selection type of regeneration cut. Past experience in California has indicated the desirability of even-aged management by clear-cutting small homogeneous units (18, 19). Small openings with soil disturbed by logging present satisfactory conditions for germination and offer more frost protection than large clear cuttings. Natural regeneration is sought when harvesting occurs during a good sugar pine seed year.

In non-seed years, the clear-cut areas should be planted or seed spotted the next spring. In southwest Oregon, the recommended practice for sugar pine management is to clear-cut and then spot seed or plant.

Early growth

First-year root development of sugar pine seedlings is rapid. The primary root, which develops as a tap root with a few short lateral branches, penetrated bare sandy soils to as much as 24 inches in 2 to 3 months after germination on the Stanislaus plots. The tap roots averaged 17 inches long. In the same time, seedlings which germinated on duff-covered soil had roots mostly 7 to 9 inches long, and a maximum of 12 inches.

4/ Unpublished data, Pacific Northwest Forest and Range Experiment Station.

Height growth is relatively slow during the first 5 years even on the best sites; however, after the fifth year growth is usually rapid. On high quality sites with little competition the first year's shoot grew to a length of 4 to 5 inches on the Stanislaus plots. Average 5-year-old seedlings were 10 inches and the tallest seedlings were about 15 inches. Average 8-year-old seedlings were 35 inches and the tallest was 73. By comparison, 8-year-old Jeffrey pines growing in the same location averaged 52 inches high and the tallest was 98 inches (35).

SEASONAL GROWTH

Seasonal height growth usually starts later than that of the associated species, except white fir (11). The average date for start of height growth at an elevation of 5,200 feet on the Stanislaus Experimental Forest was May 26. Ponderosa pine started growing about 2 weeks earlier and white fir about a month later. Sugar pine completed its seasonal growth quickly, on the average in only 51 days, and was faster than the other associated species with the exception of white fir. Half of the total height growth of sugar pine was completed within 15 days.

Seasonal radial growth starts before height growth. At the Stanislaus Experimental Forest the average date of beginning of radial growth was April 17. Also, radial growth continued for a longer period than height growth. The average was 129 days. The time and period of radial growth of sugar pine was essentially the same as that of ponderosa pine.

The new needles of sugar pine do not appear until about 80 percent of the terminal growth is completed. At the Stanislaus Experimental Forest new needles usually appear early in July.

SAPLING STAGE TO MATURITY

Growth and yield

Described by its discoverer, Douglas, as "the most princely of the genus," sugar pine grows up to 121 inches in diameter and 246 feet tall (1, 20). A tree 250 feet tall was recently reported in southern Oregon. The larger sugar pines contain 20,000 to 25,000 board-feet, Scribner rule, and the largest scale recorded was 40,710 board-feet, gross. With the exception of the giant sequoia, sugar pines on high quality sites are usually the largest trees, both in height and diameter, in the old-growth stands of the Sierra Nevada and the southern Cascade Range.

Sugar pine is long-lived; large sugar pines often are more than 500 years old. One tree 92 inches d.b.h., had approximately 600 rings outside a rotten core at least a foot across.

Sugar pine maintains its growth rate to larger sizes than do its associates, giant sequoia possibly excepted. On site II or better it will grow at the rate of 2.5 percent in basal area annually to a diameter of 30 inches (7). On the best sites, some trees may continue to make good growth up to a diameter of more than 50 inches.

In young stands, the average dominant trees 5/ attain the following sizes on medium (Dunning Site II-150) and on high sites (Dunning Site A-200) (8):

	Medium site		High site	
	Height (Feet)	Diameter (Inches)	Height (Feet)	Diameter (Inches)
Age, years:				
20	28	3	45	5
40	55	9	82	13
60	75	14	110	20
80	90	18	127	25
100	102	21	140	29
120	112	24	152	34
140	118	26	160	38

Yield table data by Dunning and Reineke (9) for young sugar pines vary considerable from these values and are believed to be too high.

5/ Average diameters are based on data compiled by Duncan Dunning, Calif. Forest and Range Expt. Sta.

In virgin central Sierra forests, dominant trees on low to high sites reached the following average heights and diameters in eight localities in California (25):

Age, years:	Height (Feet)	D.b.h. (Inches)
20	8	0.2
40	23	2.5
60	45	7.5
80	72	13.0
100	92	18.1
140	118	26.8
200	142	37.0

Sugar pine is rarely found in pure stands, except in scattered small areas, so that estimates of yields are meaningful only in relation to the whole stand. In the ponderosa pine-sugar pine type, sugar pine made up 37 percent of the total basal area of second-growth stands (9). In the virgin forest the board-foot volume of sugar pine in this type amounted to 40 percent or more of the total. One of the heaviest stands of record contained 192,000 board-feet of sugar pine on an acre plot.

On the best sites, yields of 130,000 to 180,000 board-feet per acre have been predicted for second-growth stands containing sugar pine at 100 years (9), the age at which mean annual growth culminates. However, yields of this magnitude are unrealistic. Because of the mixed species composition of stands containing sugar pine, yields of sugar pine seldom exceed 50,000 board-feet per acre. Under good management, sugar pine yields of 85,000 may be attained in 100 years on the best sites and up to 46,000 on medium sites in 120 years.

Since sugar pine does not prune itself early, even in dense stands, the many small dead branches would need to be removed in order to produce high-quality clear lumber in rotations of 80 to 120 years (fig. 3).

Figure 3.--Sugar pine does not prune itself early. These 60-year-old trees in a dense stand still have many small dead limbs.

Reaction to Competition

Sugar pine is usually rated as intermediate in tolerance (2). It is more tolerant than ponderosa pine and Jeffrey pine and less tolerant than white fir and incense-cedar. Douglas-fir is judged to be of the same level of tolerance as sugar pine where the two grow together.

Sugar pine shows good response to release. In fact, much of what is called reproduction on cut-over land actually is advance reproduction, some of which may have been 30 to 40 years old and only a few feet tall at the time of logging. After being released, the advance reproduction begins vigorous growth and subsequently is considered to have come in after logging.

In southwestern Oregon sugar pine is unable to hold the site in competition with Douglas-fir that can grow faster than 150 feet tall in 100 years.

Once behind in the competition for dominance, particularly with white fir, sugar pine declines unless released. The dominant sugar pines in the old stands undoubtedly were always dominant or were released naturally while still relatively young. Sugar pine is not a climax species but is found in the white fir climax because of its greater fire and disease resistance.

Principal enemies

Only a few of the many insects that attack sugar pine are of economic importance (22). The chief insect enemies are the mountain pine beetle (*Dendroctonus monticolae* Hopk.), the five-spined engraver beetle (*Ips confusus* Lec.), and the pine flat-headed borer (*Melanophila gentilis* Lec.). They are capable of killing young and old trees, especially those weakened by logging and fire damage. The mountain pine beetle may cause severe losses in very dense young sugar pine stands (4). The red turpentine beetles (*Dendroctonus valens* Lec.) seldom kill vigorous trees but are capable of killing weakened ones.

Relatively few diseases cause serious losses among living sugar pines. White pine blister rust (*Cronartium ribicola* Fisch.) is the most destructive disease of trees of all ages. Sugar pine is particularly susceptible to blister rust, but spread and intensification of the disease have been slow in the southern part of the range. Wind direction, summer dryness, or other factors may hinder spread of the rust. Heart rots are not a serious factor in the management of sugar pine. Losses due to rot are estimated at 3.7 to 6.7 percent for mature trees in the Sierra Nevada and from 5.6 to 11.4 percent for mature trees in the Coast Range Mountains (23, 24).

In southern Oregon 3 percent of trees 24 to 50 inches in diameter were cull and 10 percent were partly defective; 4 percent of trees larger than 50 inches were cull, and 29 percent were partly defective. [6] *Fomes pini* (Thore) Lloyd and *Fomes laricis* (Jacq.) Murr. are the most destructive of the wood-rotting fungi attacking sugar pine. In many localities, dwarfmistletoe (*Arceuthobium campylopodum* f. Engelm. *blumeri* (A. Nelson) Gill) is a serious parasite on both young and old trees.

Saplings and poles of sugar pine are readily killed by fire. However, mature and older trees have some measure of resistance, as attested by the fire scars prevalent in the old-growth forests.

SPECIAL FEATURES

The very large seeds of sugar pine were a source of food for the Indians. They ate seeds as nuts or ground them into a paste, called lopa. Lopa was used especially in feasts (3).

6/ Hammond, H. L. Report on the work of the South Umpqua combined disease survey and timber cruising party. Umpqua National Forest office report. 1942.

This pine got its name from the sugary material, pinitol (monomethyl-D-inositol), found as exudations on the bark of the tree. This sugar alcohol was used by the Indians as a food and in solution as an eye wash. It also has cathartic properties.

The oleoresin of sugar pine was found to contain 65 percent l-alpha pinene, 13 percent l-beta pinene, 10 percent of a bicyclic sesquiterpene of cadalene type, 2 percent of a sesquiterpene alcohol, provisionally named lambertol, and 2 percent unidentified polyterpenes (30).

RACES AND HYBRIDS

There is no evidence so far to show the presence of races of sugar pine. But it would not be surprising to find that races do occur, in view of the 15-degree spread of latitude over which the tree grows and of the discontinuous distribution in the southern part of its range. No natural hybrids are known to exist, but sugar pines have been crossed with Armand's pine (*P. armandi* Franch.) and with Korean pine (*P. koraiensis* Sieb. & Zucc.) (6).

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